Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S10 A2

On the use of Hidden Markov Models to investigate airfoil stall dynamics

[1]Konstantinos Kellaris*; [2]Yu Ding; [1]Marinos Manolesos;

[1]*School of Mechanical Engineering, National Technical University of Athens, Athens, Greece*

[2]*Stewart School of Industrial and Systems Engineering, Georgia Tech, Atlanta, GA, USA*

Abstract

This study investigates the application of Hidden Markov Models (HMMs) for identifying the different flow separation regimes in stall cells present in the flow past thick airfoils. Stall cells, large-scale structures of three dimensional flow separation and reattachment, play a significant role in the aerodynamics of wind turbine blades, especially for high angles of attack. In these regions, airflow detaches from the surface, leading to intermittent variations in lift and drag that can reduce efficiency and induce fatigue in turbine structures. Understanding the behavior of the stall cells and the transitions between various flow separation regimes is crucial for improving the design and formulating flow control strategies of wind turbine blades.

Using wind tunnel data from two different thick airfoils, this work applies HMMs to classify and predict the flow separation states. The data includes surface pressure and integrated load measurement, and the study focuses on the ability of HMMs to capture the complex and stochastic nature of the flow under stall conditions. The HMMs model the different flow separation regimes as hidden states, with measurable flow features such as pressure or lift force as emissions. These hidden states correspond to different stages of the flow, including attached flow, partial separation, and fully detached flow. The HMMs are able to identify transitions between these different regimes, providing deeper insights into the dynamics of flow separation states. The results demonstrate that HMMs offer a promising approach for the detection of flow separation regimes under the presence of stall cells, which are difficult to characterize using conventional methods. This approach enhances our understanding of flow behavior past thick airfoils, offering new possibilities for optimizing wind turbine blade design and stall cell detection and characterization as well as control strategies.

Keywords: Hidden Markov Models, Aerodynamics, Separated Flow, Stall Cells, Thick Airfoils